

Claims

1. A process of producing fermentation product comprising the steps of,
 - (i) forming an acidified suspension of particulate plant derived material comprising a first polysaccharide which is more readily hydrolysable and a second polysaccharide which is more difficult to hydrolyse,
 - (ii) allowing the first polysaccharide to undergo hydrolysis by action of the acid at a temperature of at least 50°C under conditions such that the first polysaccharide is hydrolysed and thereby forming a mixture of an aqueous liquor containing dissolved sugar and a solid residue containing the second polysaccharide,
 - (iii) subjecting the mixture to one or more separation stages in which the solid residue and aqueous sugar liquor are substantially separated from each other,
 - (iv) optionally washing the residue substantially free of the acid and the sugar,
 - (v) passing the solid cellulosic residue to a further treatment stage in which the residue is subjected to the action of dilute acid at a temperature of at least 50°C under conditions such that the second polysaccharide is hydrolysed and thereby forming a mixture of an aqueous liquor containing dissolved sugar and a solid residue,
 - (vi) subjecting the mixture to one or more separation stages in which the solid residue and aqueous sugar liquor are substantially separated from each other,
 - (vii) optionally washing the residue substantially free of the acid and the sugar,
 - (viii) adjusting the pH of the aqueous liquor from stages (iii), (iv), (vi) and (vii) to a pH of at least 4,
 - (ix) passing the aqueous liquor from stage (viii) to a fermentation stage where the dissolved sugars are acted upon by a microorganism in a fermentation broth to produce a fermentation product,
 - (x) separating the fermentation product from the broth,characterised in that the separation stage in steps (iii) and/or (vi) is assisted by

flocculation of the waste by-product, employing one or more flocculating agent(s) selected from the group consisting of water-soluble polymers, water-swellaable polymers and charged microparticulate material.

2. A process according to claim 1 in which the plant derived material comprises materials selected from the group consisting of herbaceous biomass, softwood biomass, hardwood biomass, sewage sludge, paper mill sludge and the biomass fraction of municipal solid waste.
3. A process according to claim 1 or claim 2 in which the plant derived material is cellulosic and comprises hemicellulose as the first polysaccharide and cellulose as the second polysaccharide.
4. A process according to any of claims 1 to 3 in which the acid has a pKa of below 4 and has a concentration up to 2% by weight.
5. A process according to any of claims 1 to 4 in which the acid is selected from sulphuric acid and hydrochloric acid.
6. A process according to any of claims 1 to 5 in which the hydrolysis of the first polysaccharide is conducted at a temperature of between 120 to 220°C for a period of from 1 minute to 15 minutes.
7. A process according to any of claims 1 to 6 in which the hydrolysis of the second polysaccharide is conducted at a temperature of between 120 to 220°C for a period of from 1 minute to 15 minutes.
8. A process according to any of claims 1 to 7 in which the flocculating agent is selected from the group consisting of water-soluble or water-swellaable natural, semi-natural and synthetic polymers.
9. A process according to claim 8 in which the polymer is formed from a water-soluble monomer or blend of monomers.
10. A process according to claim 8 in which the polymer is selected from the group consisting of polyacrylate salts, polyacrylamide, copolymers of acrylamide with (meth) acrylic acid or salts thereof, copolymers of acrylamide with dialkylaminoalkyl (meth) acrylate or acid addition or quaternary ammonium salts, polymers of diallyldimethyl ammonium chloride, polyamines and polyethylene imines.
11. A process according to any of claims 1 to 10 in which the flocculating agent

is a charged microparticulate material.

12. A process according to claim 11 in which the charged microparticulate material is selected from the group consisting of swellable clays, anionic, cationic or amphoteric microparticulate silica based materials and organic cross-linked polymeric microparticles.

13. A process according to any one of claims 1 to 12 in which flocculation is effected by employing a water-soluble or water-swellaable polymer and a charged microparticulate material.

14. A process according to any one of claims 1 to 13 in which flocculation is effected by introducing an anionic microparticle material into the mixture and then reflocculating by adding a substantially non-ionic polymer.

15. A process according to any one of claims 1 to 14 in which flocculation is effected by introducing a cationic polymer into the mixture and then reflocculating by adding an anionic microparticulate material.

16. A process according to any one of claims 1 to 15 in which flocculation is effected by introducing a cationic polymer into the mixture and then reflocculating by adding an anionic polymer.

17. A process according to any one of claims 1 to 16 in which flocculation is effected by introducing an anionic polymer into the mixture and then reflocculating by adding a cationic polymer.

18. A process according to any one of claims 1 to 17 in which the solid-by-product material comprises lignin.

19. A process according to any of claims 1 to 18 in which the fermentation product is selected from the group consisting of ethanol, glycerol, acetone, n-butanol, butanediol, isopropanol, butyric acid, methane, citric acid, fumaric acid, lactic acid, propionic acid, succinic acid, itaconic acid, acetic acid, acetaldehyde, 3-hydroxypropionic acid, glyconic acid and tartaric acid and amino acids such as L-glutaric acid, L-lysine, L-aspartic acid, L-tryptophan, L-arylglycines or salts of any of these acids.

20. A process according to any of claims 1 to 19 in which the fermentation product is separated from the broth by passing the broth comprising the

fermentation product into a distillation stage, where the fermentation compound is collected as a distillate and the residue 'still bottoms' is removed.

21. A process according to any one of claims 1 to 20 in which the fermentation product is separated from the broth by passing the broth comprising the fermentation product into a concentration stage, in which the fermentation compound is collected in the concentrate and extracted by at least one means selected from the group consisting of ion exchange, solvent extraction and electrodialysis.